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Some Conceptual Problems in Nuclear Proliferation

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The Proliferation Problem

A world in which many more countries acquire nuclear weapons could be a much more grim one. Wars that today kill thousands might instead kill millions; wars that now are averted might instead be launched, simply because each side preemptively felt it had such powerful weapons that it dared not hesitate to use them.

To prevent a further spread of nuclear weapons, the United States and the Soviet Union have offered for signature a Nuclear Non-Proliferation Treaty (NPT) freezing the number of states possessing such weapons at the current five—the U.S., USSR, Great Britain, France, and Communist China.[1] Countries possessing nuclear weapons pledge themselves under the treaty not to give them away or to assist other nations to produce them. Countries not yet having such explosives pledge themselves in the same treaty never to accept them and never to manufacture them. The latter "nonweapons" states moreover would agree to accept inspection safeguards by the International Atomic Energy Agency (IAEA) on all their peaceful nuclear activities, to ensure that such facilities and materials are not diverted to producing nuclear explosives.

The United States and Soviet Union came to agreement on an NPT text between the fall of 1967 and spring of 1968, and the treaty was offered for signature on July 1, 1968; ratifications by 43 states, including the U.S., USSR, and Great Britain, were required for the treaty to go into effect. Acceptance of the NPT was delayed somewhat in the aftermath of the Russian intervention in Czechoslovakia, but on March 5, 1970, Soviet and American ratifications were deposited together with those of enough other nations to activate the treaty. Among nonweapons nations with significant nuclear industries, only Canada and Sweden thus far have signed and ratified the NPT; West Germany, Italy, India, Japan, Australia, Israel, Brazil, and Argentina are some of the other states potentially capable of producing nuclear weapons.[2]

At first glance, we might interpret any foreign resistance to the NPT as indicating a malicious craving for nuclear weapons. More honorable and acceptable arguments can be advanced for opposing the treaty, however—arguments which will induce real political debate in the countries involved. Even if a nation has no intention of ever producing nuclear weapons, it might relish the legal *option* of producing them, for the political concessions this can produce, or simply for the prestige of being on an equal legal footing with the "superpowers." Surrendering the weapons option can also have economic costs. Scientists have argued that valuable spinoffs in the peaceful application of atomic energy may be lost if weapons research is rigorously and explicitly forbidden, since the technologies often overlap. More important, there are definite costs in the verification process which the IAEA would install to assure outside powers that materials were not being diverted to weapons. Nations being inspected will have to detail trained and expensive personnel to accompany IAEA inspectors on their rounds. In some cases existing equipment might have to be redesigned to make adequate monitoring possible. At other times more detailed and costly bookkeeping procedures will be required. At the extreme, it might even be necessary to shut down operations in some facility to confirm records on the fissionable materials it contains.[3]

States allowed to retain nuclear weapons under NPT may openly or secretly welcome the binds it imposes on the countries which never get into the "nuclear club." States denied such weapons will resent such binds on themselves, but may welcome the bind on other "nonweapons" states. The debate on the NPT, or on alternative barriers to the spread of nuclear weapons, will thus take varying forms from country to country. National values will be crucial to the trends of such debates, as will the particular political and economic situations of the countries involved. Technical opinions will also be crucial, as each society consults its physicists on the priorities and opportunities involved, asking such questions as: "If we retained our legal option to make bombs, how long would it take us to acquire them?" "How far are our neighbors from the bomb?"

Yet authoritative answers here can easily be misunderstood within a conceptual confusion on "how close" nation X or nation Y is to making an atomic bomb. Depending on context and political biases, clearly different answers will be supplied in response to seemingly identical questions. The intent of this article is thus to explore the semantic ambiguity which appears in physicists' answers to politicians' questions on proliferation.

If we ask how far Japan is from the bomb, we might get an estimate of "three years." This answer does not tell us that Japan will have a bomb in three years; yet neither does it assure us that three years from now Japan would still have to wait three years for a bomb. Perhaps three years is the minimum required if a deliberate effort is expended; yet if no explicitly military effort is expended, will the time-lag remain the same?

What will concern most of us is not the earliest date at which six or eight countries can have bombs; there may be no evidence of crash programs in any of these states. Rather we must fear what the time-lag for any hypothetical deliberate crash program will asymptotically sink to, simply as the result of the more innocent civilian-purpose steps already being taken in each country. The following diagram is intended to clarify some of the distinctions involved here:

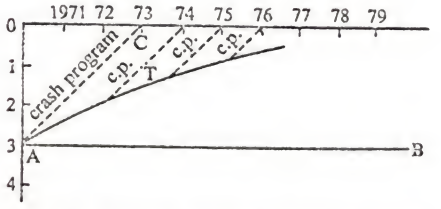

Figure 1. Innocent progress toward the bomb.

The vertical axis indicates the number of years it will take some nation to produce nuclear weapons of Nagasaki magnitude if it begins at any particular date. The horizontal axis specifies, on an identical scale, years of the future for which the above scale applies. AT illustrates what may be a typical curve. By the very definition of the axes, no curve can approach the zero time-lag line more rapidly than at a 45 degree angle (AC). If Sweden were defined as being four years from the bomb and started her crash program now, she in four years would be zero years from the bomb. Any 45 degree line, any line parallel to AC, is a crash program line. (For the moment, we are only discussing time-lags to production of *bombs;* if delivery systems are judged important, these can be added to the analysis as suggested later in this article.)

The concept of a "crash program" may be a little fuzzy. Political decision-making bodies will typically see certain "satisficing" points[4] at which they are doing "all that can be done" to secure some weapon. From our disinterested perspective, we might see this as a rationalization; perhaps one can *always* achieve still more rapid results if one only will spend still more money; perhaps not. The lengths of time assumed for "crash programs" here thus reflect the probable willingness of states to devote resources to the race, once an explicit move toward nuclear weapons has been approved.

Why are the questions posed on such a graph relevant? Why indeed should the outside world care *how far* any particular state is from acquiring nuclear weapons? We of course prefer that this state not have such weapons, so we hope that it will be *some* distance from them. If this distance is a little greater, moreover, we can expect to detect any deliberate move to acquire bombs before it is successful, while we still will have time to initiate political, economic, or even military retaliatory moves. We hope that anticipation of such detection and retaliation will deter the move for the bomb in the first place. The longer the time-lag until a bomb could be produced, the more time for the outside world to notice and react to such a move, and the greater the deterrent to it. In the worst or tensest situation, the sanction for any perceptible grasping for bombs might be war and nuclear attack. Sanctions far short of this might suffice, however, as with general political condemnation by the outside world, the freezing of assets and remittances, or the imposition of some sort of embargo.

The Shrinking Time-Lag

One might now venture to contemplate the characteristics of the normal curve (AT). Why does it not stay horizontal and parallel to the zero line (AB); why does the time-lag not stay constant for a nation not actively seeking to acquire nuclear weapons? A number of factors

[1] The text of the Nuclear Non-Proliferation Treaty as finally presented can be found in United States Arms Control and Disarmament Agency, *Documents on Disarmament: 1968* (Washington: U.S. Government Printing Office, 1969), pp. 481–485.

[2] A full discussion of the spreading potential for nuclear bomb production, and efforts to control the spread, can be found in C. F. Barnaby, ed., *Preventing the Spread of Nuclear Weapons* (London: [illegible] Press, 1969).

[3] A basic analysis of the costs and problems of inspection appears in Arnold Kramish, "The West and the Unwatched," *Adelphi Papers* (Institute for Strategic Studies, London) 36 (June, 1967).

[4] The "satisficing" concept is of course drawn from Herbert Simon, "A Behavioral Model of Rational Choice," *Quarterly Journal of Economics* 69 (February, 1955), 99–118.

can be predicted here to bring even the most innocent nations ever closer to the bomb.

Economic needs for electrical power may encourage or require the building of power reactors. Some power reactors are fueled with natural uranium, which is freely available in a number of countries, precluding any external inhibitions to supply. Others are fueled with enriched uranium, which, although it must typically be purchased from a source like the United States, may lend itself more easily than natural uranium to further enrichment to weapons-grade U-235. Either of such reactors produces plutonium as well as electrical power. Plutonium, when the economics of power production justify it, can be processed again in a chemical separation plant for use as fuel for various kinds of reactors. Over time larger quantities of plutonium or enriched uranium will thus come into circulation in various countries. National plants for the production of plutonium or enriched uranium will also become commercially advisable. Plutonium and enriched uranium both can be adapted for use in a bomb.[5]

Quite independently of this production of fissionable materials, basic research may be undertaken on how such material would be assembled into bombs. This may not be inspired by any direct desire to manufacture weapons, but merely by an interest in "pure research"; or it may follow incidentally from research in related practical civilian fields such as controlled fusion or breeder reactors. The need for possible civil defense measures against other nation's bombs may similarly stimulate such research; so will simple patriotic concern that other nations are undertaking similarly basic enquiries. (Thus, for instance, in Sweden basic research has been done on bomb designs although atomic bombs have never been assembled.) If the laboratories required for these investigations are small enough, their activities may be impossible for outside agencies to monitor, and to verify their findings may require nothing so momentous as an actual test detonation.

In general the discoveries of other nations in the nuclear field will steadily leak out, often in straightforward academic publications. Peripheral equipment similarly will become available in world markets at lower costs, perhaps even in cases in which the entire kit would previously have had to be constructed indigenously. Finally, the infrastructure of trained personnel and functional organization will tend to grow in most nations so that any program as sizable as weapons development will be more feasible.

At first, the AT curve may be almost parallel to an AC military crash-program curve, since all the bomb-relevant basic research that could be undertaken will emerge almost naturally in any event. Abstractly, the United States in 1900 was doing all it could do (was on a "crash program") to produce nuclear weapons. So is Upper Volta today. At such an early stage, almost no additional money could be profitably spent to accelerate a bomb capability. Governments and legislatures thus are able to speak of "no need yet to make a decision" on nuclear weapons. All that can be done is being done. This may merely evade a decision for the early years of a nation's nuclear development, but a need for choice definitely emerges later, when the nation must deliberately decide whether an optimal military program will be undertaken or avoided. Yet if such a program is not undertaken, the remaining effort required for bomb-production may still always be decreasing.

One can argue that this menacing overlap between civilian and military nuclear technology is nothing new, for responsible officials have been alert to it for years. No one expects the IAEA inspectorate, which will have primary responsibility for inspecting peaceful nuclear installations under NPT, to spend most of its time watching for autonomous and explicitly military programs; the focus of attention will instead be on the civilian activities which in their natural growth more ever nearer to the military line. Any reader of the evolving IAEA safeguards documents since 1961 will be impressed by their ingenuity in closing all major gaps through which materials might slip unnoticed into bomb manufacture.[6]

IAEA, based in Vienna, came into existence in 1959 and since then has engaged in a mixture of inspection and international technological assistance activities. Inspection has involved materials and equipment which might otherwise be utilized for the production of nuclear explosives; IAEA practices have required access to records on the utilization of such materials, as well as verification of records by inspection of the fuel or equipment itself. IAEA inspection experience has been accumulated under three circumstances to date: when the Agency has itself arranged for the transfer of equipment or fuel, when a technical-assistance agreement between two states has designated IAEA as the inspection agent in place of the donor state, and when a state has unilaterally asked the Agency to apply safeguards over some or all of its facilities.

If bomb capabilities are coming a little closer now, the addition of an international inspection or safeguards system can still serve to alert the outside world after a deliberate bomb program has been launched and before it reaches fruition. After completion, it may be more difficult for the outside world to impose any retaliatory sanctions. Indeed, after the bomb program has reached fruition, the nation involved may want to publicize rather than to hide it.

Yet this IAEA vigilance may not relieve our concern but only prove how well taken it was. In effect the ingenuity of IAEA safeguard documents illustrates the running of a possibly hopeless race. The inspectorate must watch what is legitimate, to be certain that nothing illegitimate (i.e., lacking civilian purpose, moving toward explosives) is undertaken. As more and more activities become legitimate—not only reactors, but reprocessing plants, separation plants, and perhaps soon uranium diffusion plants—the inspectors must follow along, watching always a new zone of legitimacy, to make certain that the next "illegitimate" zone is not entered.

As projects justifiable in civilian terms bring nations ever closer to nuclear weapons, the time-lag will continually be shrinking. And even with the presence of an IAEA inspectorate, the outside world may find it impossible to detect a bomb program early enough for meaningful reprisals. Perhaps the IAEA could not even disclose a bomb program as early as the country itself wanted it disclosed; past a certain point, a nation will want to advertise and proclaim the fact that it has decided to violate its NPT commitments.

Questions also can always arise about whether we really know with certainty how far Israel or Canada or Sweden is from a bomb. Without inspection, the extent of militarily useful nuclear progress in a country may be difficult to determine; even with such inspection, a certain percentage of the fissionable material in an advanced commercial system might be undetectably divertable to military uses.

Zero Time-Lags

One might then question whether the AT curve will inevitably reach the zero time-lag line, or whether it will level off at some relatively even distance from it. Perhaps by the very definition of the curve, some gap would always have to remain, for the AT curve describes progress where there is no intention to manufacture nuclear explosives. One can theoretically conjure up a reactor design that would be exactly identical to a bomb, but this happily is unlikely, so that an absence of intent to assemble bombs would presumably keep them from coming into existence. There will thus always be some final work to be done, some final questions to be answered, before bombs would be available. Perhaps three months is a reasonable estimate of the residual time-lag at which we would asymptotically level off; this may be too pessimistic or too optimistic.

A nation may thus wait "just short" of nuclear weapons, as the result of its full development of peaceful nuclear industry. Yet much will depend on how it waits. Some states might elect to allow plutonium to accumulate first, before designing and building any models or prototypes of bombs; this would allow honest disclaimers that no "work on bombs" was under way. Others might move right ahead with prototypes, so as to speed the final production of bombs whenever the international situation seemed to require it. Perhaps India is in the first category today, and Israel may be in the second. Once work on bomb design has been done, however, it cannot easily be undone, as scientists do not quickly forget what they have learned. If a computer simulation has once been run on the design of a bomb, the country which has commissioned it has been moved that much closer to possession of bombs: for an indefinite time into the future, the time-lag until actual weapons production may have been reduced from months to a matter of weeks.

With the necessary margin of explicitly military activity so slight, the temptation to begin and complete a crash program might become very great, especially for nations which have not signed a treaty renouncing nuclear weapons. The mere desire for scientific tidiness may stimulate the manufacture of the bomb, to prove out all the speculation as to whether it could now be easily done. Fears of some preemptive intervention by a hostile state (perhaps

[5] Good basic accounts of the overlap of military and peaceful nuclear technology can be found in Leonard Beaton, *Must the Bomb Spread?* (London: Penguin Books, 1966), and Alastair Buchan, *A World of Nuclear Powers* (Englewood Cliffs, N.J.: Prentice-Hall, 1966).

[6] Comprehensive accounts of the evolution of IAEA practice can be found in Arnold Kramish, *The Peaceful Atom and Foreign Policy* (New York: Harper and Row, 1963), and Lawrence Scheinman, "Nuclear Safeguards, the Peaceful Atom, and the IAEA," *International Conciliation*, 572 (March, 1969).

one also immeasurably close to bombs) might similarly stampede a nation into crossing the line (see ATN, Figure II); "ten bombs in a cave" may be a better deterrent to war than "ten bombs anytime, at twelve weeks' notice."

If such reasoning on preemptive war is at all correct,[7] one could even question whether peace is best served by trying to hold back nations at such a short distance from bomb stockpiles. Nations with no imminent conflicts with their neighbors may indeed be better off never having touched the zero-line. Those under the shadow of attack might behave less nervously, however, if the line had already been crossed. If assured second-strike forces are preferable to preemptible forces among the great powers, they might also be preferable for some small-scale confrontations.

Legal Obligations

One should thus consider the impact of the obligations imposed by the Nuclear Non-Proliferation Treaty, as well as by other international agreements. NPT commits a nation not to make nuclear weapons, and to accept international safeguards to ensure that it is complying. A nation may withdraw from NPT upon giving three months' notice.

Perhaps more binding still are the various bilateral agreements whereby nations accept equipment or nuclear fuels from abroad, under the agreement that such resources will not be used for military purposes, and again that their use will be subject to international safeguard. Even after three months' notice, such resources cannot legally be used for military purposes, but must either be returned or kept safeguarded for civilian use. Development of domestic fuels or reactor designs may have been postponed because such international offers were commercially more attractive. It can thus be argued that such bilateral arrangements, as with the American AEC, are more effective in delaying nuclear weapons than is NPT.[8]

Yet the combination of NPT plus nuclear assistance may be the most effective restraint of all. Nations having formally renounced nuclear weapons will be more willing to let their domestic independent nuclear options atrophy, to

[7] The reasoning on preemptive and surprise attack is spelled out quite fully in Thomas Schelling, *Strategy of Conflict* (Cambridge, Mass.: Harvard University Press, 1960), pp. 205–254.

[8] See Jan Prawitz, "A Nuclear Doctrine for Sweden," *Cooperation and Conflict*, 1968:3, pp. 184–193, for an account of the diverting of Swedish nuclear activities from military to purely civilian purposes, in part through the acceptance of foreign (American) assistance.

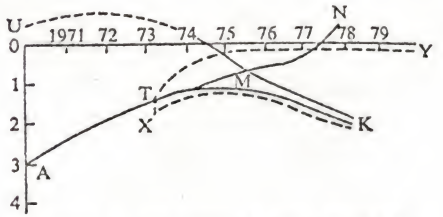

Figure 2. The impact of legal restraints.

be replaced by external assistance. Nations which have been seduced into becoming dependent on outside assistance will be more willing to go ahead to sign NPT. The combination of the two restraining influences can be greater than the sum of their independent influences.

The presence of a treaty obligation thus forces us to discuss "legal" and "illegal" crash programs, distinctly defined by varying degrees of treaty violation. How long will it take an NPT-signatory nation in 1975 to manufacture bombs, if it seizes safeguarded stocks of fissionable materials (i.e., arresting and deporting, or simply ignoring, the IAEA inspectorate)? How long, if it instead openly and honestly revokes the treaty, giving the proper notices, surrendering or returning all safeguarded equipment and materials, beginning afresh to produce and accumulate plutonium free of any international legal commitment? Our "illegal" curve (ATY) will show the physical capability of an NPT-signatory for cases in which it is prepared to ignore its treaty obligations completely. The "legal" (ATXK) curve conversely shows time-lags to the bomb for cases in which such treaty obligations are to be respected, that is, if no price in "international reputation for law-abiding behavior" is to be paid.

The distinction between "legal" and "illegal" crash programs is important, at least because it is another source of the semantic confusions under examination here. When asked how long it will take his country to make a bomb in 1975, some scientists will answer with reference to strict adherence to treaty obligations, others with total indifference to such obligations.

The ATN curve shows how capabilities might have developed if there had been no NPT. When compared to this "no-treaty" curve, signing NPT may thus have brought a nation closer to bombs for an interim period, at least via potential "illegal" bomb programs. Signing up probably has given a nation access to greater outside assistance in nuclear technology, and induced a greater foreign tolerance of

big reactor projects or of plutonium-enrichment plants. Looking at the "legal" curve (ATXK) however, one sees that the bomb program time-lag has been increased. First, there is a flat addition of three months notification, at the date of signature. Second, the signatory state thereafter may be more likely to accept fuels and facilities under IAEA safeguards from other countries, rather than maintaining indigenously produced nuclear fuels and facilities, probably because these will be much more efficient and economical; hence the establishments legally free of bans on military use will actually begin to atrophy. The time-lag for "legal programs" will thus gradually expand again to level off at some number of years instead of months.

One must note that this latter "legal" ATXK curve will at best be a benchmark. It indicates what a state can do with roughly as much legal dishonor as would have been incurred in a bomb program before the treaty had been adhered to. In actuality, the benchmark may become unrepresentative in one direction or another. International morality might come to disapprove strongly of any state's exercising even its legal prerogative of withdrawing from the treaty; alternatively, international morality might come to tolerate states violating the treaty, when they were severely threatened, even without ever formally withdrawing from it.

Increasing Time-Lags

It will be interesting to examine the ways in which the curve could move away from zero, as the time-lag grew. Theoretically it is possible for a nation to lose its proficiency at physics, if scientists were to be driven out of the country or if research programs were allowed to wither for lack of funds (ATMK). Something like this happened in Germany between 1930 and 1935; if the Weimar Republic had survived, it could have had the atomic bomb earlier than Nazi Germany; as it happened, the German "crash program" curve moved away from zero during the years in which Jewish and other physicists were driven to leave the country.[9]

For another example, a nation that already has a nuclear stockpile and destroys it will have increased its "time lag" (UK). If all facilities capable of producing fissionable material were to be dismantled, this would widen such a gap even more.

Other possibilities exist, for there are some irreversible processes in the exploitation of economic opportunity. A nation might at some point have to choose between investing in a large power reactor project, or in a similarly extensive hydroelectric facility. Either of these would supply electricity, and would lower the market price of such electricity enough to make the other redundant. A military crash program that also produces needed electricity can be assigned a lower explicitly "military" price tag, and can be funded more rapidly and generously. Suppose that the hydroelectric project were built. If the electrical needs of a country thus had been satisfied by alternative means, the probable speed of any crash program would be reduced and the time-lag to weapons increased. All such pricing and costing thus depends on the environmental assumptions. Many nuclear electrical projects can conversely be rated as profitable if, and only if, the plutonium produced is explicitly assigned the higher market value of military purposes.

Even within the nuclear field, newer and more profitable technology may over time require less handling of fissionable materials, although the current trend is clearly in the opposite direction. As absolute weapons-capable facilities are thus closed down, to be replaced by newer non-weapons-capable plants, the time-lag to weapons would naturally grow again in countries not consciously pursuing weapons.

One might still vaguely cherish the hope that weapons-grade uranium or plutonium will never be required for any commercial purpose, that the fuels for power reactors can always be less pure. If this were so, the innocent processes of commercial development could indeed leave states still far from bomb capabilities. And if that were so, the Nuclear Non-Proliferation Treaty could indeed have been written still more tightly, to ban explodables as well as explosives, to preclude the possession of fissionable materials by any state outside the current five weapons states. Yet the exact definition of what is fissionable would require disclosure of relatively classified military information, and the facts here may never be settled for all time. For the U. S. or USSR to inform the world of the exact purity of uranium or plutonium required for a bomb might only accelerate the proliferation process. Research reactors may inevitably require weapons-grade materials in any event and so may certain power reactors some day.

A nation may similarly be induced by commercial consideration to depend on a foreign supply of enriched uranium or on foreign reprocessing of plutonium, thus again slowing

[9] See Robert Jungk, *Brighter than a Thousand Suns* (New York: Harcourt, Brace and World, 1958) for a fascinating account of the distribution of nuclear expertise in the 1920s and 1930s.

and making commercially redundant any indigenous national program legally free to produce weapons. But here we are returning to the distinction between legal and illegal crash programs introduced above. In many circumstances, such a legal barrier would slow moves toward bombs just as much as physical obstacles would. In other cases, however, legal scruple will count for less. Even so "law-abiding" a country as Sweden might consider illegally seizing safeguarded plutonium or enriched uranium to make some bombs if a foreign army seemed about to cross its borders and advance on Stockholm. For the most dire circumstances, every advanced nation might thus become a short-time-lag nuclear weapons state, unless the physical technology of nuclear energy were to move countries away from this capability.

It was earlier argued that the international inspector's explicit function will soon be made obsolete by the shrinking of the "time-lag to bombs." Perhaps the Non-Proliferation Treaty could thus have been better written without any provision for inspection, and so could the bilateral agreements by which nuclear-weapons states give technological and material assistance to nonweapons states. Inspection promises to pose many problems, in terms of the sheer cost of accommodating such international visitors, and the threats of commercial espionage or simple misunderstanding. Yet it would be an overstatement to say that international inspectors would serve no purpose any more once the crucial time-lag had fallen below six months. By their very presence, they may lengthen the physical time-lag.[10]

To be in with a relatively trivial point, no one can be certain that a bomb program would not still be detected somehow by the inspectors wandering around the premises. Since estimates of secrecy will have to be probabilistic, the addition of a safeguards system may yet deter a bomb program, out of fear that the outside world would be roused before the program could be completed. Even if they could no longer detect a bomb program any earlier than the cheating government wanted them to, the inspectors in position will be a continual and visible reminder of the state's treaty obligations, a reminder that some international retaliation will come after bombs are acquired, no matter how late it comes. Violating NPT will be a delicate decision for any state; if forgetting about international feelings were to make it easier for some state to decide to go ahead, the presence of inspectors will make these harder to forget.

The presence of inspectors generally upsets the legitimacy of purely national decisions on nuclear weaponry, in effect undermining the sovereignty of the nation in the nuclear field. It will be less easy for the crucial physicists to see a clear pattern of duty for themselves; some may become confused enough in their loyalties to betray a national bomb program to the IAEA representative passing through. Inspectors moreover make it more difficult for outside states to forget or back out of their threats of reprisal; the insult is compounded when one's nationals on duty as inspectors are ignored and defied.

Finally the IAEA safeguards procedures, however inadequate, force the government in question to institute national auditing and control systems which otherwise might not be established. With international inspection, any move to a bomb will at least require making an explicit national decision, rather than allowing the development to go forward by default. In states which otherwise might have let small cliques of scientists or military men launch military weapons programs, the inspectorate may thus forestall a bomb acquisition.

Exceeding the Crash Program

One must also reexamine the assumption that the curve cannot approach the zero-line at a more severe angle than 45 degrees (AZ). The time-lag at point A is defined only by conditions within the country in question. Naturally, every nation has a zero time-lag when another state already possessing nuclear weapons is prepared to give some away. The definition also excludes drastic redefinitions of the country in question; e.g., if the Common Market on short notice were to become sovereign, Luxembourg in that short time would have become (part of) a nuclear weapons state. The time-lag we will normally cite for Luxembourg assumes that there will be no merger with France and no gifts of nuclear warheads from the United States. But what if a group of French physicists tomorrow flee to exile in Luxembourg (perhaps bringing stolen fissionable material with them)? This may give the country a bomb by 1972, yet our curve for 1970, did not show a two-year time-lag. Indeed, to take a real-life example, could one have predicted in 1925 that the United States was only 20 years from the atomic bomb? With even J. Robert Oppenheimer studying in Germany, the balance of scientific talent might have suggested 1955 as

[10] Some of the following argument was made earlier in a broader arms control context by Lawrence S. Finkelstein, "New Trends in International Affairs," *World Politics*, 18 (October, 1965), 117–126.

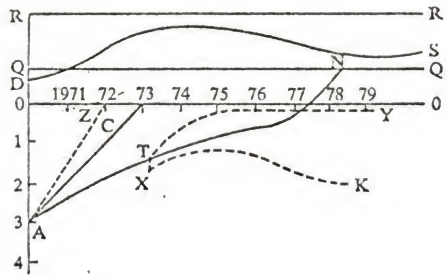

Figure 3. Redefinition of the baseline.

the bomb-acquisition date for the United States (and 1942 for Weimar Germany).[11]

The vertical axis on our graphing thus shows only the probable duration of a crash program utilizing the resources and technical manpower likely to exist in the country at any given time. It represents a prediction of how long military crash programs would take, and of how other programs will function in lieu of crash programs, given the current scientific potential available to particular national governments.

Redefinition of the Baseline

To add a semi-trivial category of conclusions to those already spelled out, we may differ as to what our zero time-lag line should represent. When we ask, "How far is Australia from the bomb?" do we mean only one Nagasaki-type plutonium bomb (probably not), or twenty such bombs, or one hundred; or do we mean hydrogen-bombs (if we do not find ordinary A-bombs particularly significant); or do we mean bombs plus "first-rate" delivery-systems? Scientists frequently give reassuringly long time estimates for some country's bomb program, and then afterwards explain that these estimates were meant to refer to a "sizable" stockpile, or to include extensive development of military bomber or missile systems.

Such longer estimates often will not be so reassuring; "two plutonium-bombs, delivered by an Israeli airliner" may not be insignificant. The variations here might be shown additively by using alternative baselines drawn parallel to each other (O-O, Q-Q, R-R) to distinguish various levels of accomplishment. By definition it takes longer to produce 50 bombs (R-R) than to produce 10 (Q-Q). Delivery systems, if they are relevant, may be more variable in their expansions of the time-lag. One could try to predict how available such systems will become "naturally" (i.e., with no explicit military intent) in the future. If a Boeing 707 were a ready-made bomber in 1961, perhaps SAM missiles reduce its effectiveness today. Conversely, if many nations decide to invest in space research, perhaps intermediate-range missiles will come to be close at hand for many of the countries which are about to acquire plutonium bombs. The zero baseline for "bombs-plus-delivery systems" might thus be a curved line (D-S), so that the time-lag for full military capability would be accurately shown.

[11] This is of course a somewhat speculative extrapolation from the evidence offered by Jungk, *Brighter than a Thousand Suns*.

Summary

The graphic formulation used here is intended to show the range of answers possible for the set of questions, "How far is India from the bomb?" The confusion and multiplicity of answers is of more than academic interest, for it shows that reassuring the outside world on one question in this range may not always be consistent with reassurance on another. Stemming the spread of nuclear weapons may not be hopeless, but it also may not ever be definitively accomplishable. There may be an important distinction between legal and illegal capabilities, once a treaty has been introduced, such that we will have to measure *political* capacities for violating treaties as carefully as *physical* capabilities. We will also have to consider the ranges of time-lags that bring a nation "too close" to a bomb, so close that opposing states would be tempted to try preemptive attacks, so that actual possession of bombs might have been preferable, so close that serious steps should be considered somehow to widen the time-lag.

Above all, the anticipation of nuclear proliferation may exhibit many of the same reiterative strategic calculation problems as does deterrence after the weapons are acquired. "How far is Japan from a bomb" may not be as important a question as "How far is Japan from being three months from a bomb"; the answer to the latter question may set some preemptive wheels whirring, in ways we wish to avoid.